DATA DRIVEN XR FOR SPACE MISSIONS USING NASA OPEN SOURCE

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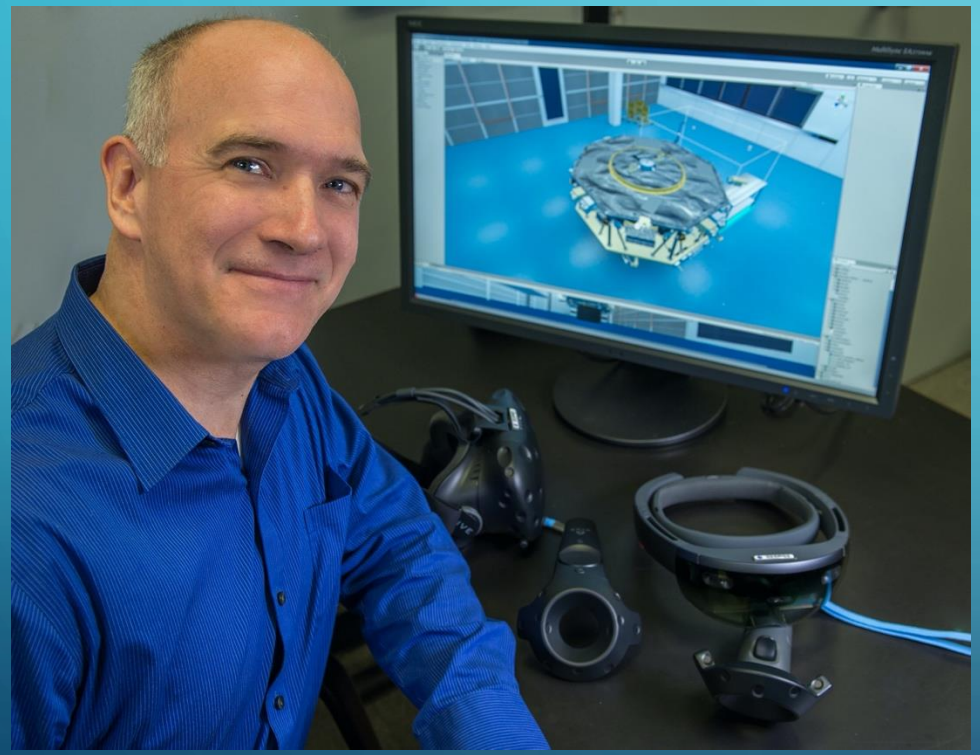
NASA GSFC AR/VR PRODUCT DEVELOPMENT LEAD

AGENDA

- Introduction
- NASA Open Source Solution for Data Driven XR
  - Rapid Model Import Tool (RMIT)
  - Goddard Mission Services Evolution Center (GMSEC)
  - Mixed Reality Exploration Toolkit (MRET)
- Putting It All Together
  - Engineering
  - Science

ABOUT ME



- 33 year NASA Employee
- GMSEC Developer 2006-2008, Acting Technical Lead in 2008
- AR/VR Development Lead at GSFC since 2016 (and PDL since 2018)

GSFC AR/VR RESEARCH & DEVELOPMENT LAB

THOMAS G. GRUBB, AR/VR PRODUCT DEVELOPMENT LEAD

The Mission Beyond Reality

- Started in 2016 using combination of IRAD, CIF, and organizational funds
- Initial survey of XR Use Cases across center
- Collaboration
  - GSFC Center Organizations (SED, ExIS, GMSEC)
  - Missions (OSAM-1 and Roman Space Telescope)
  - Scientists & Engineers
  - Universities (UMBC, UMD, UNT, JHU/APL, BSU)
  - Other NASA Centers

NASA OPEN SOURCE SOLUTION FOR DATA DRIVEN XR

HELP ESTABLISH A NASA OPEN SOURCE ECOSYSTEM FOR COLLABORATIVE XR, REDUCING AGENCY-WIDE COSTS OF XR AS WELL AS REDUCING LONG TERM RISKS FOR XR COMMUNICATION.

NASA OPEN SOURCE SOLUTION FOR DATA DRIVEN XR

3D MODELS

Rapid Model Import Tool (RMIT) – Converts CAD models to XR-ready gLTF models

DATA

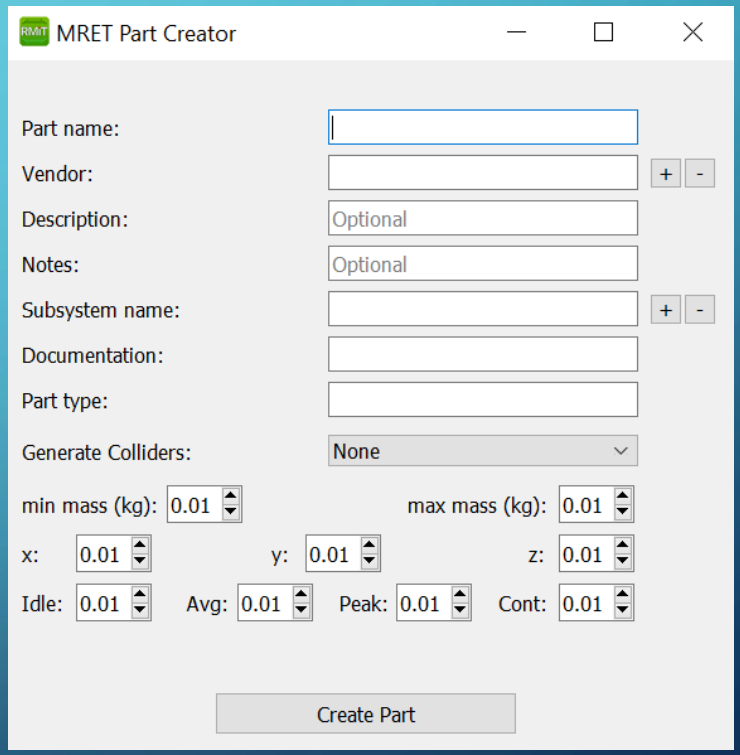
Goddard Mission Services Evolution Center (GMSEC) – Loosely coupled publish/subscribe middleware for Mission Operations and other domains. Standardized messages now OMG standard

XR

Mixed Reality Exploration Toolkit (MRET) - Rapidly build XR environments for NASA domain problems

RAPID MODEL IMPORT TOOL (RMIT) - NASA OPEN SOURCE TOOL FOR CAD CONVERSION

- Import 3D models built in commercially available Computer Aided Design (CAD) and Digital Content Creation (DCC) development software such as; Catia, Creo, 3DS Max, Maya, etc.
- Processes models to reduce file size and exports the results in glTF format, compatible with AR and VR development software applications.
- Requires Blender and Unreal Engine
- Batch or interactive mode
- Integration with MRET Part format*
- Open Source Alternative for PiXYZ
- To be integrated into



*Next RMIT Release

- Originally designed to loosely couple Mission Operations Centers' (MOC) components, enhancing
  - Integration
  - Maintenance
  - Automation
  - Situational Awareness
  - Component and Middleware Replacement (avoid vendor lockin)
- Standardized Publish/Subscribe Messaging API
- Standardized Messages (now OMG standard)

GMSEC – MISSION ENABLER

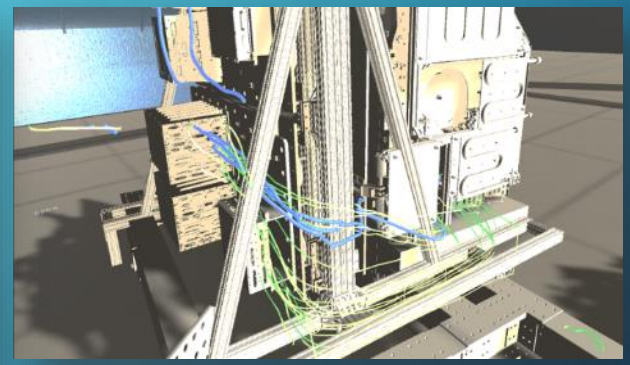
- Enhances
  - Integration
  - Maintenance
  - Automation
  - Situational Awareness
  - Component and Middleware Replacement (avoid vendor lockin)
- Wide Industry support for MOC components
- Open Source components and middlewares (reduces cost)
- GMSEC is NASA and Space Force Approved
  - Authority to Operate with approximately 20 GSFC and ARC missions and 10 Space Force missions

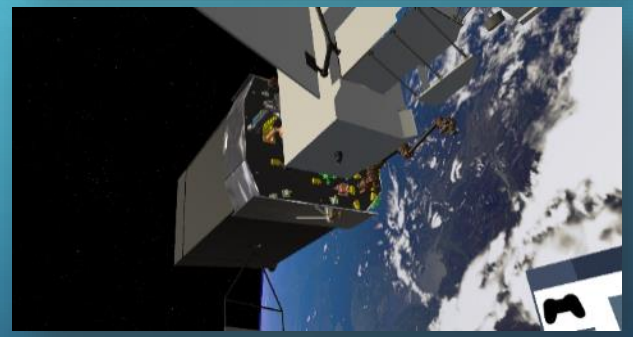
Not just for Mission Operations!

MRET

MIXED REALITY EXPLORATION TOOLKIT

- Goddard-Developed Software for rapidly building XR environments for NASA domain problems, e.g., pulling in CAD models of thermal vac chamber and Roman Space Telescope to do fit checks
- Collaborative, cross-domain, mission lifecycle support tool for Science and Engineering
  - Integrates NASA "models" (scientific models, point clouds and LIDAR data, and engineering, CAD-based models)
  - Common tool set available in AR/VR/Desktop (e.g., measurement tools, voice commands, notes, animations, lunar and planetary lighting models, etc)
  - Access to NASA data sources. Easy to use and powerful secure communications infrastructure for all VR NASA applications using the Goddard Mission Services Evolution Center (GMSEC) architecture
- Primarily VR but limited AR has started rolling out as of September 2021



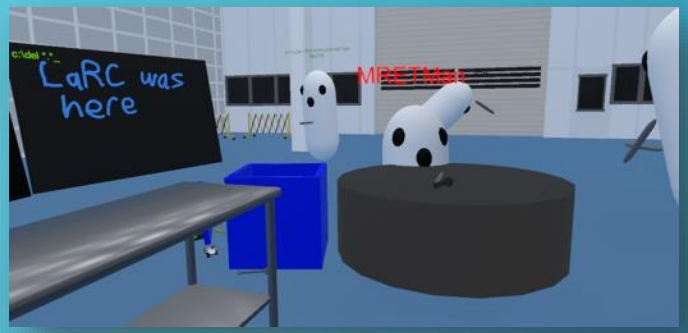


MRET has been officially released as NASA Open Source and is available through https://software.nasa.gov

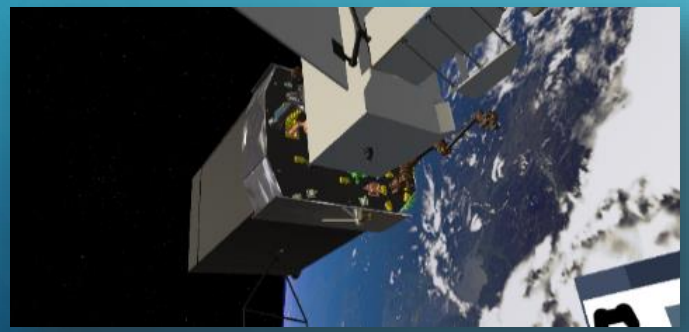
MRET HIGHLIGHTS

COMBINE 3D MODELS, POINT CLOUDS, AND TERRAINS

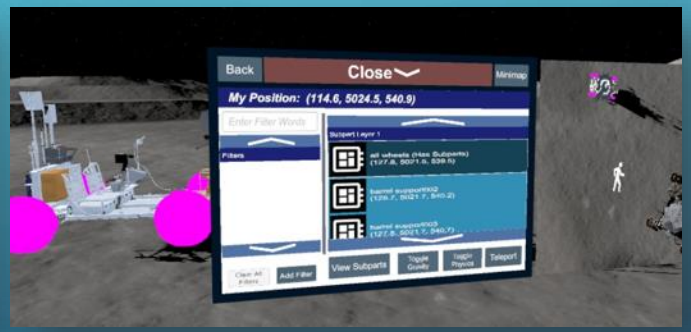
FOR VR AND PC DESKTOP (LIMITED AR)



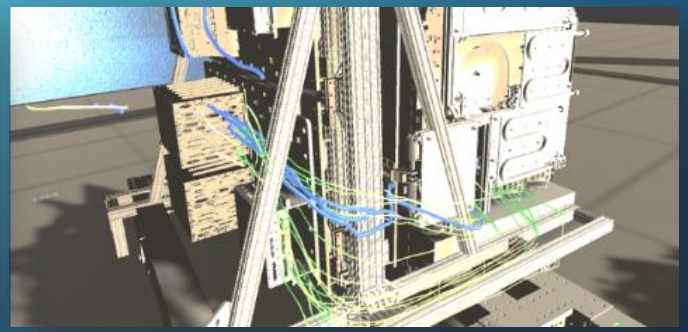
COLLABORATE ON SECURE NETWORKS AND OVER VPN



DRIVE MODELS FROM REAL-TIME TELEMETRY. INTEGRATES WITH GMSEC, ROS, MATLAB, SPICE, AND 42



PROJECT BASED TOOL FOR RAPIDLY BUILDING XR ENVIRONMENTS FOR NASA DOMAIN PROBLEMS



COMMON TOOLSET, E.G., MOVE, MEASURE, DRAW, VOICE, NOTES, ANIMATION…

MRET – NASA OPEN SOURCE XR FOUNDATION FOR SPACE MISSIONS

- https://github.com/nasa/Mixed-Reality-Exploration-Toolkit (Incl Built version)
- Lines of Code: ~30K
- Main Subsystems: 7 (UI, Locomotion, Input, Project, Collaboration, Tool, Data)
- MRET leverages non-open source software (14 free and paid Unity plugins), including
  - Point Cloud Viewer and Tools
  - Final IK
  - Embedded Browser
  - UMP (Win, Mac, Linux, WebGL)

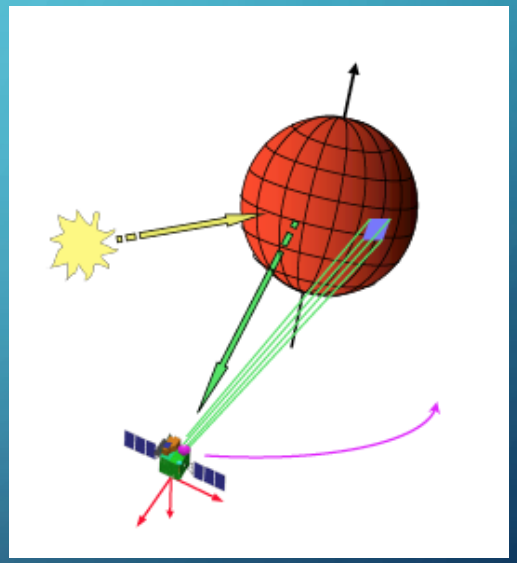
LEVERAGING PARTNERSHIPS

Virtual Data Explorer	University of Maryland Baltimore County
Hardware support*, ROS#	University of Maryland College Park
Human Factors Studies*	University of North Texas
AR User Experience*	Johns Hopkins Applied Physics Laboratory

*MRET Future Release

INTEGRATION

- GMSEC
- MATLAB
- SPICE
- Virtual Data Explorer (VDE)
- ROS#
- Rapid Model Import Tool (RMIT)
- NASA IoT Platform*
- NASA 3D Shared Object Repository*



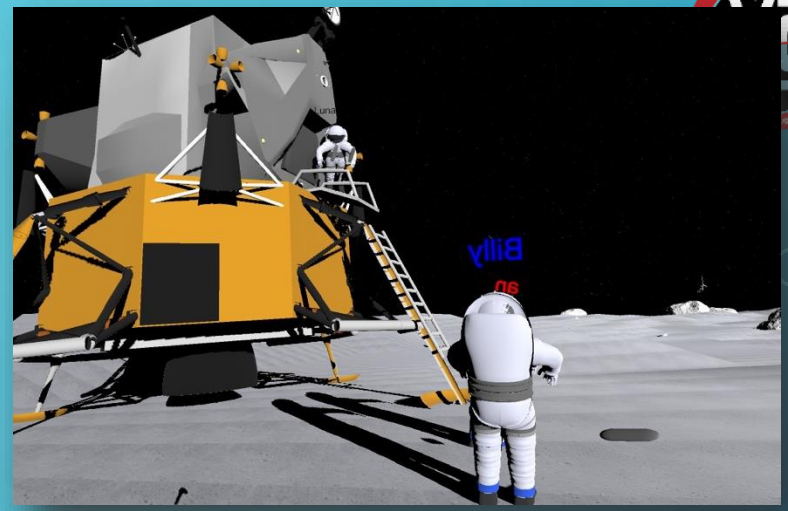
* Not yet funded

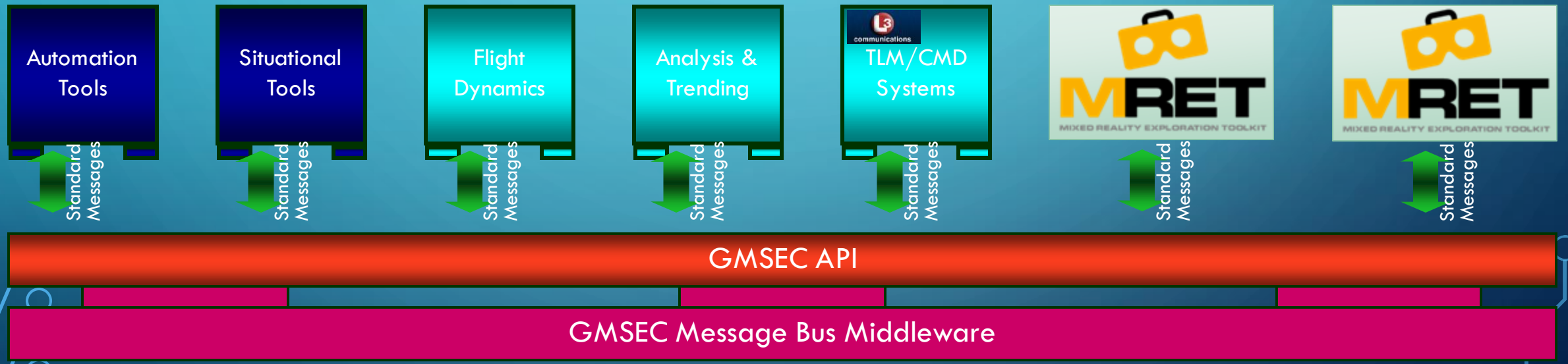
GMSEC AND MRET

MRET is GMSEC-Compliant

- Other GMSEC Components can drive VR, e.g., provide situational awareness by subscribing to real-time telemetry messages to drive 3D models of spacecraft
- MRET can use GMSEC for collaboration, allowing collaborative sessions on secure networks, even over VPN

Situational Awareness, Automation)





MRET INTEGRATION WITH STANDARD COMMUNICATION MIDDLEWARES

GMSEC

Integration with the General Mission Services Evolution Center (GMSEC) to get spacecraft/instrument telemetry and secure XR collaboration

ROS

Integration with the Robot Operating System to get robotic telemetry

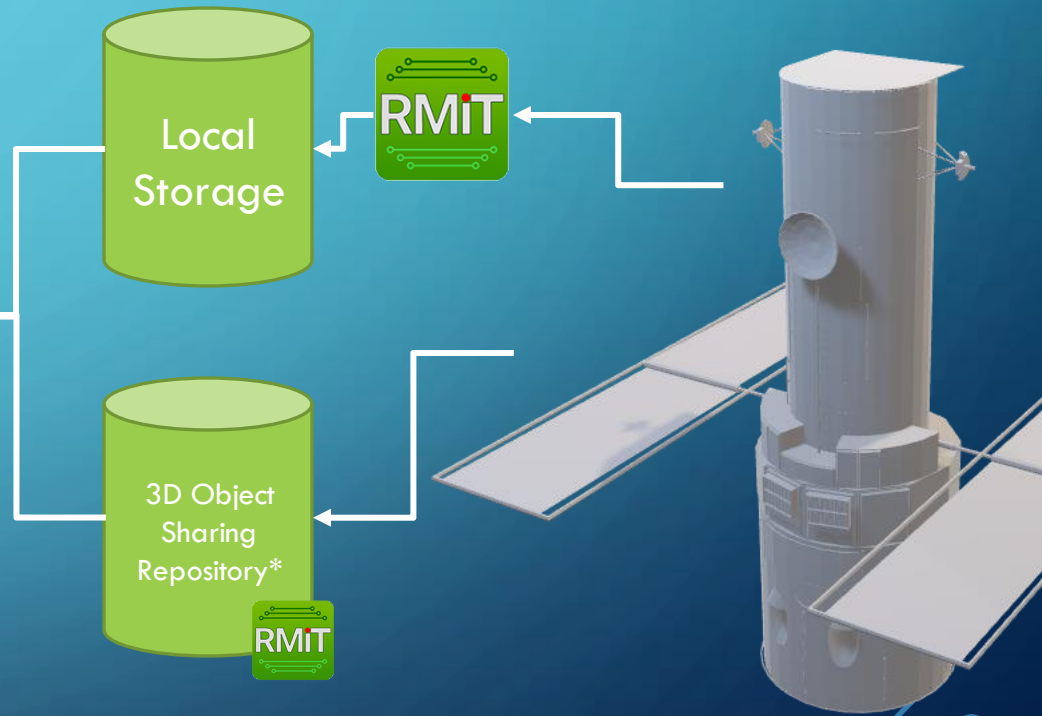
NASA IOT PLATFORM*

Integration with NASA Internet of Things (IoT) Platform to get industry standard telemetry and control/interact with systems

* Not yet funded

REDUCE COST/RISK AND BARRIER TO ACCESS XR

- Get 3D Models into XR
- Get Data
- Collaborate



ROS/IoT* provide other standardized data

* Not yet funded

PUTTING IT ALL TOGETHER

LOTS OF USE CASES OUT OF THE BOX

- Concept Design
- Previsualization
- Hardware I&T (Fit checks, planning, training)
- Situational Awareness (Operations)
- Network Topology
- Science Visualization (Point Clouds, Terrains)

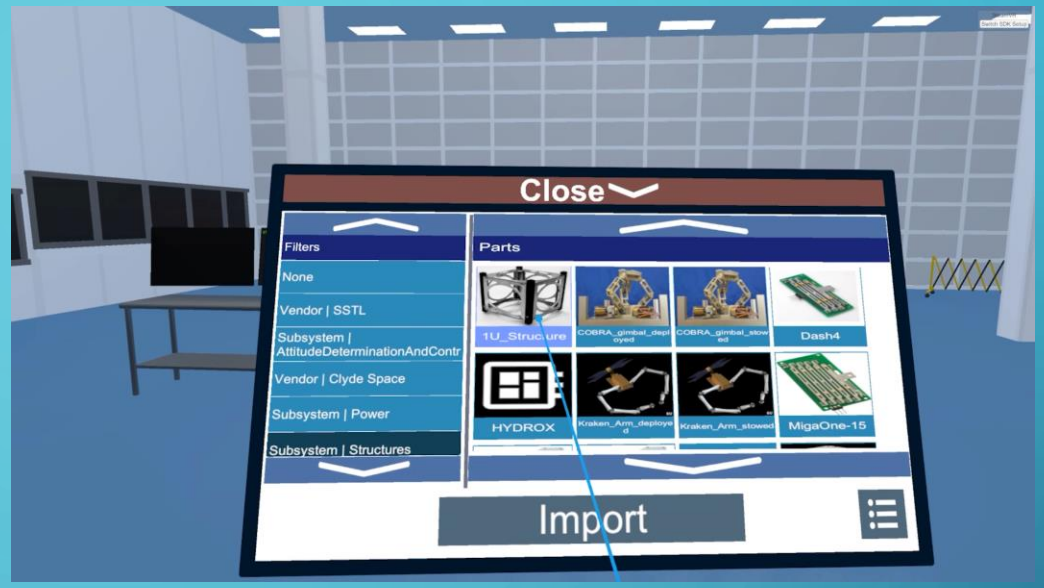
COLLABORATION – THE KILLER APP OF XR

- Dispersed groups can work together and share information via a common 3D space using XR
- Remote Members can oversee and contribute either through MRET Desktop or Teams
- Reduces number of people who have to be physically co-located for work (Social Distancing), help overcome covid safety rules

ENGINEERING DATA

CONCEPT DESIGN

- Concept Design and Pre-Phase A proposal process
- Integrated Part Browser of 3D models (converted from CAD)
- Part Metadata can include vendor, mass, power, subsystem, etc
- Perform Fit-checks and Tool paths Early
- Master Equipment Lists
- Included Example Collection of off-the-shelf (OTS) Cubesat parts

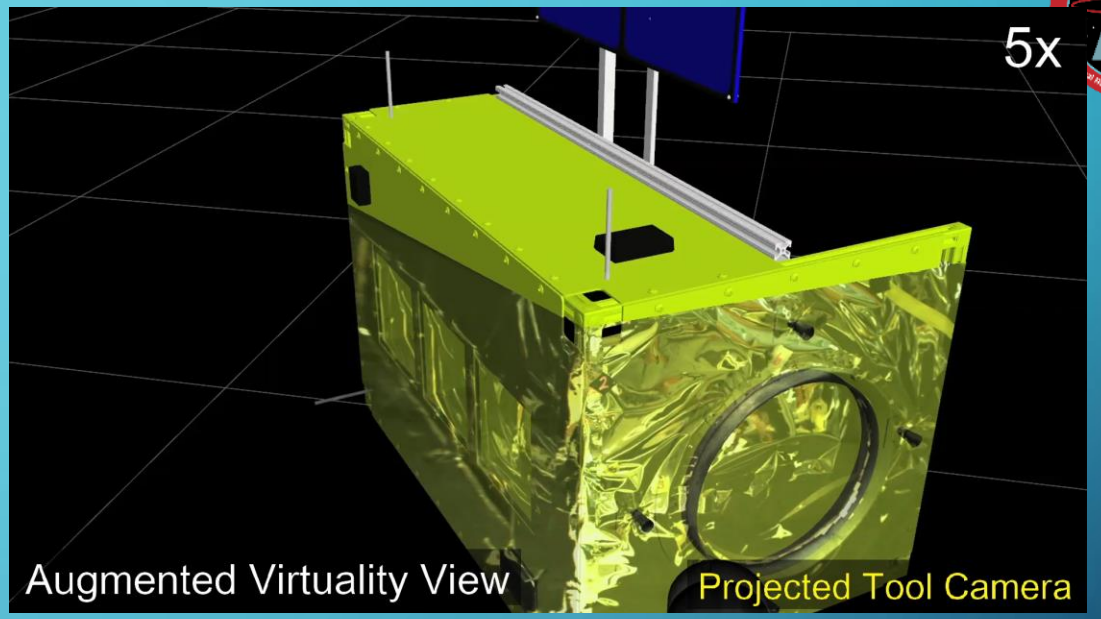


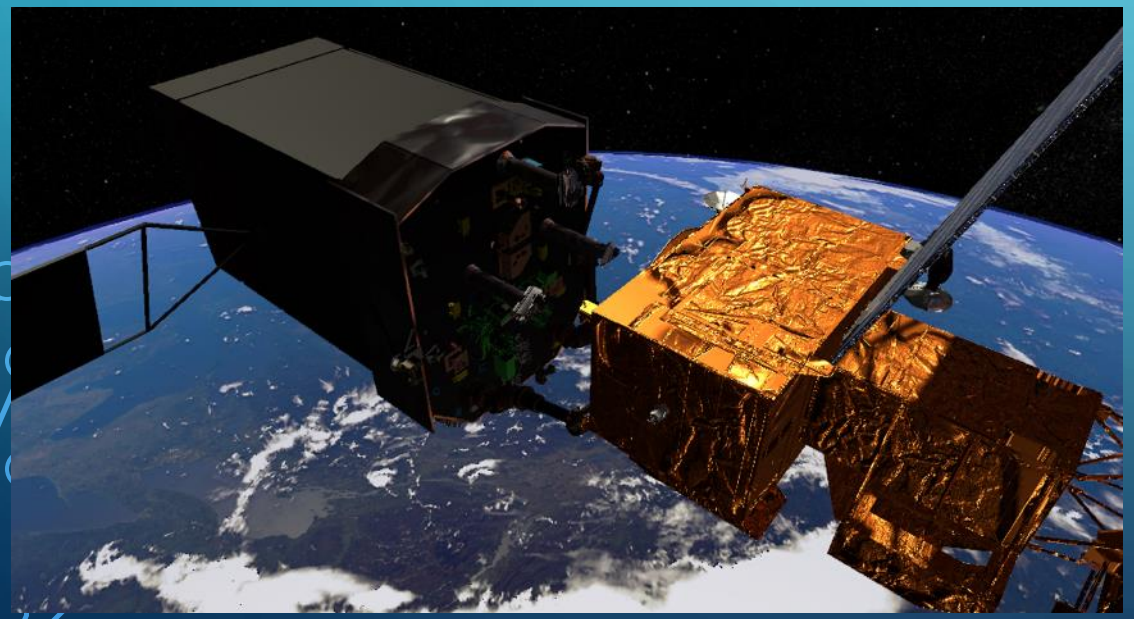
ORBITAL VISUALIZATION FOR SITUATIONAL AWARENESS

- Visualize spacecraft and instrument orbit and pass information
  - Spacecraft attitude, orbit, and even deployment
  - Connections with ground stations
  - Instrument swathes and views
- Driven by telemetry from GMSEC/ROS#

SPACECRAFT SITUATIONAL AWARENESS

- Enhanced situational awareness with 3D simulations of spacecraft or robots and environment for better visualization of operations
- XR can be used for closer inspection of on-orbit conditions, with views from any angle
- More intuitive comprehension of procedures, depth and clearances than with 2D screens
- Connect XR scene **to live on-orbit** for operational use
- Driven by telemetry from GMSEC/ROS

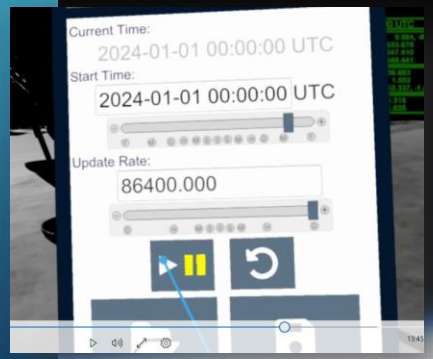


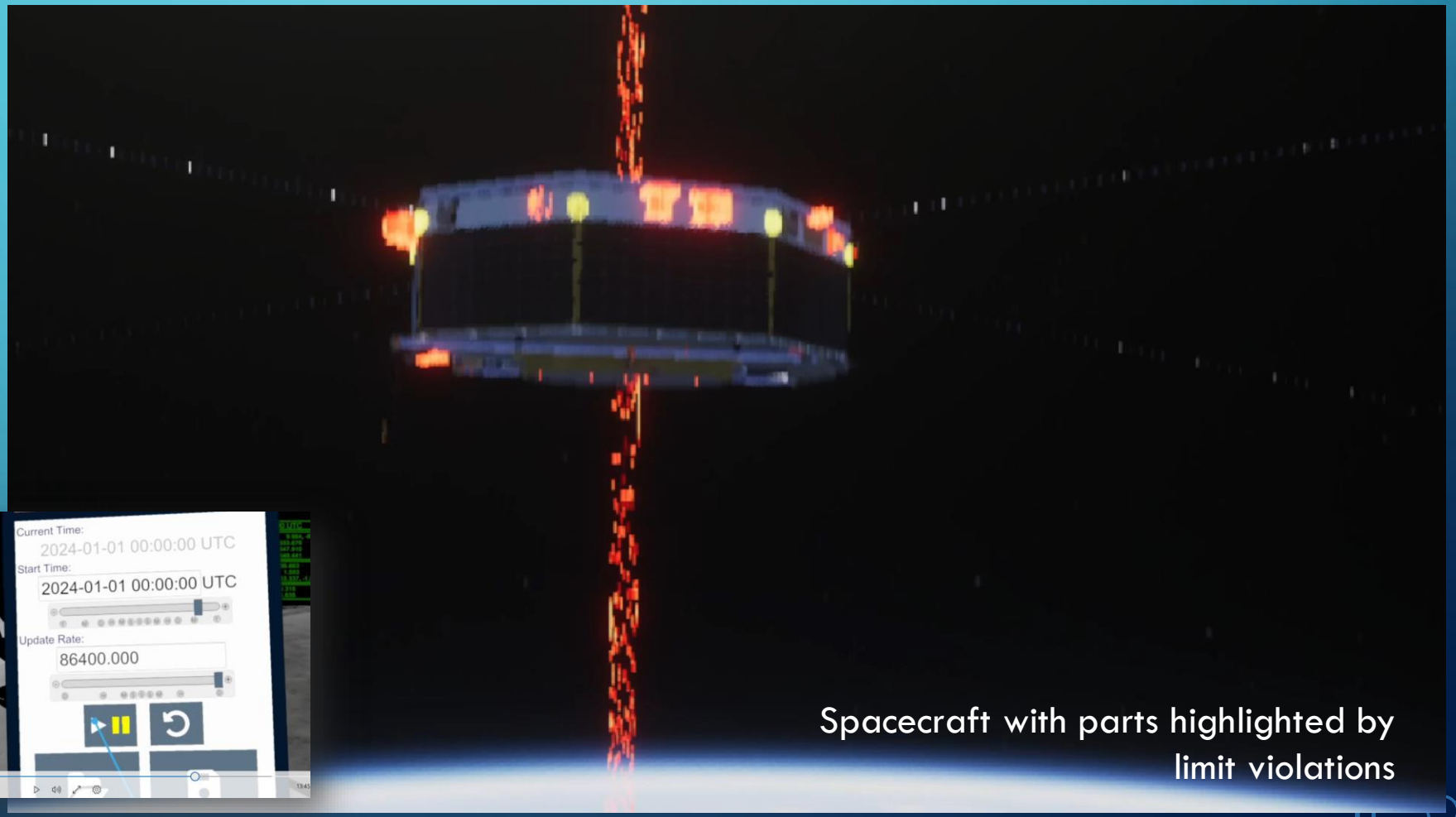


Augmented Virtuality courtesy of Johns Hopkins University Laboratory for Computational Sensing and Robotics (LCSR)

IN-DEPTH SITUATIONAL AWARENESS AND ANALYSIS

- Visualize 3D model of spacecraft and instruments with mnemonic value overlays and even color changes
- Combine with the ability to scrub forwards and backwards in time to help analyze timeline of events (Future)
- Digital Twin of Orbital Assets
- Driven by telemetry from GMSEC/ROS



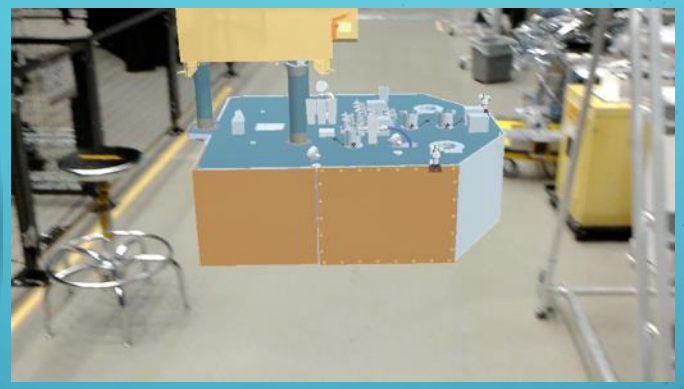


Spacecraft with parts highlighted by limit violations

HARDWARE INTEGRATION & TEST

Physical World

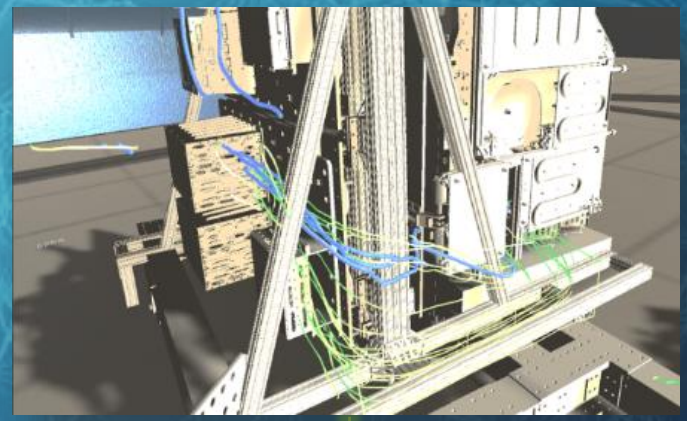
- I&T
- Live Telemetry Display
- Documentation
- QA Oversight



Augmented Reality

- Planning
- Fit Checks
- Reach & Access
- Harness Routing
- Training
- Walk-throughs

Digital World



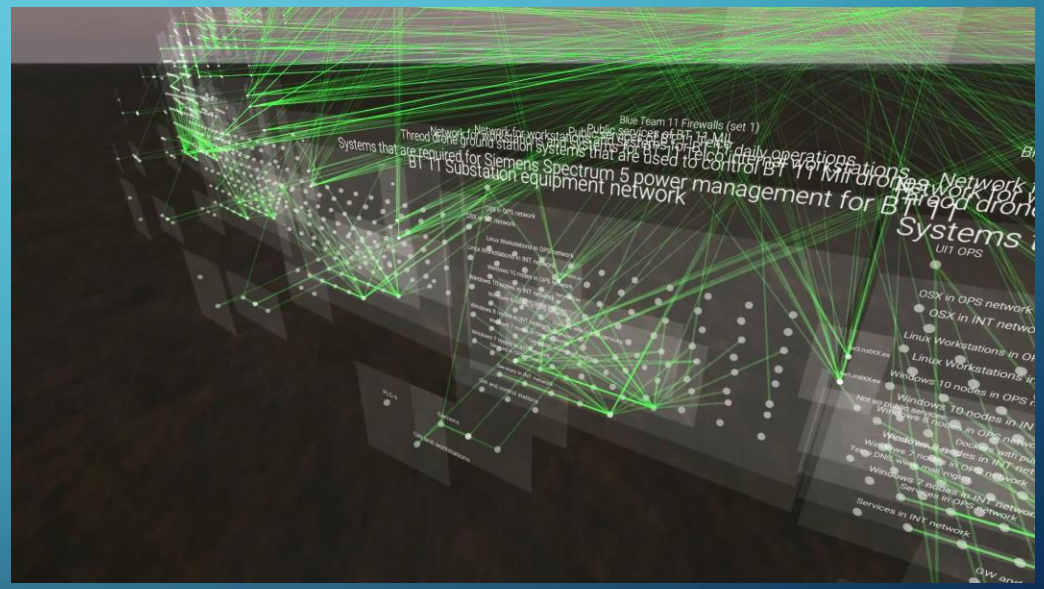
Virtual Reality

- Planning
- Fit Checks
- Reach & Access
- Harness Routing
- Training
- Walk-throughs
- Pre-Viz

FY22

NETWORK STATUS & ANALYSIS WITH MRET + VDE

- Accurate situational awareness of larger Mission Ops network topology. See entities' status in both physical and functional space.
- Transfer knowledge of the network's topology and expected / normal behavior to incoming network operators.
- VDE (Standalone) has been used to visualize NATO and NATO Cooperative Cyber Defence Centre of Excellence (CCDCOE) Cyber Defense Exercises (CDX) datasets both during the Locked Shields exercise and in various conferences and demos



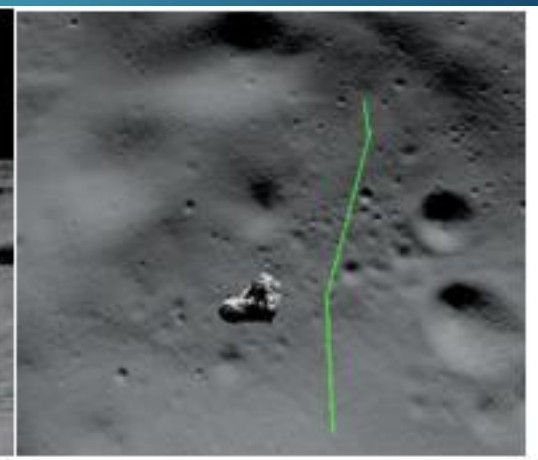
SCIENCE DATA

LUNAR SOUTH POLE VR

- For scientific evaluation of dynamic surface conditions (sunlight, geology, topography) to plan & visualize future missions
  - Challenging terrain, dramatic lighting conditions, different geology than Apollo
  - Terrain from LOLA data, with procedurally generated lunar rocks and hi-def textures for sub-5 meter views
  - Dynamic Lighting Tool based on actual Lunar location and Sun position
  - Lunar Textures and Assets
  - Interactive EVA science tools
- Mission Operations could be driven from telemetry, Science point cloud data could be overlaid

Procedural rocks on the lunar surface

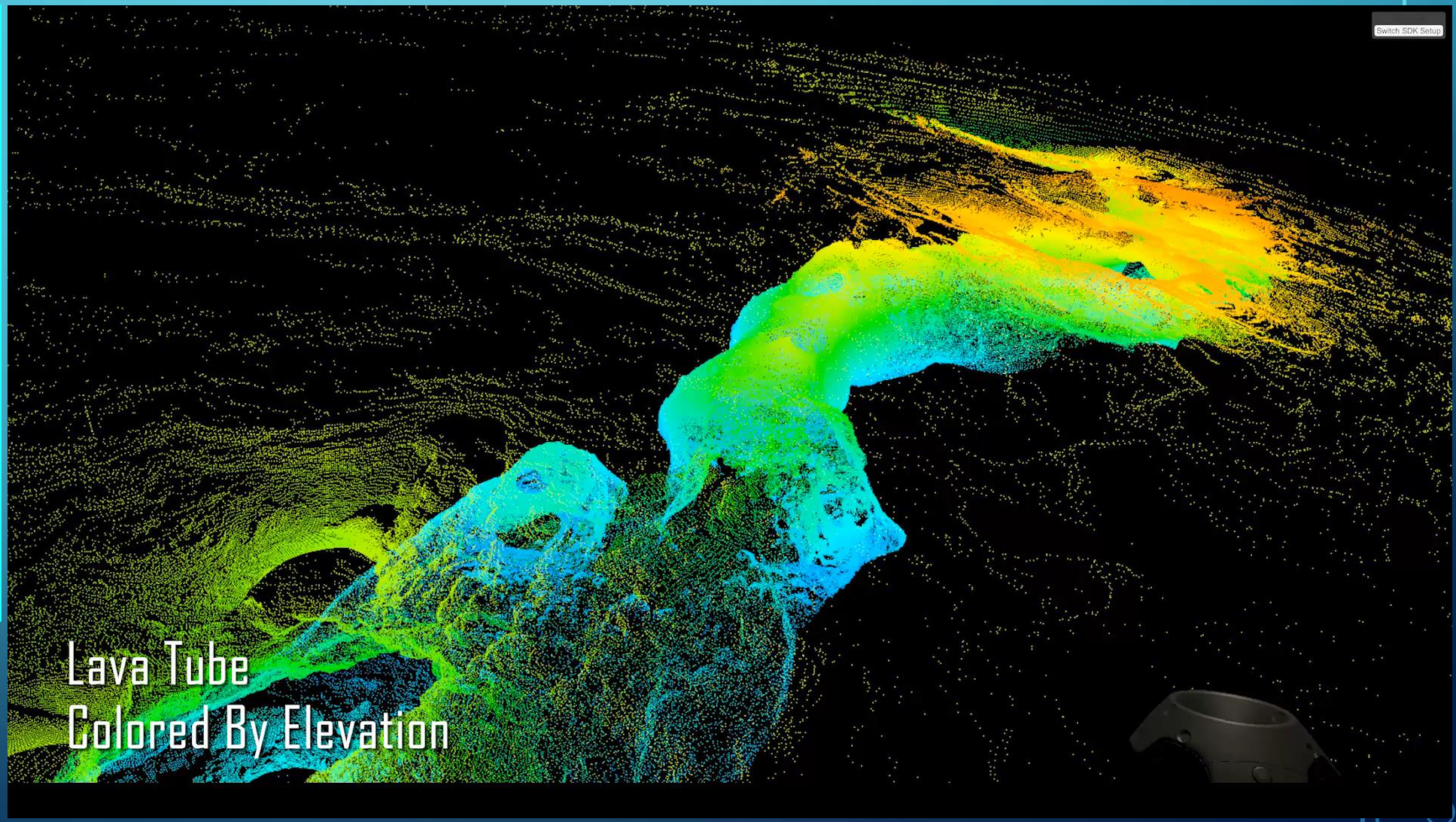
Lightweight path terrain visualization



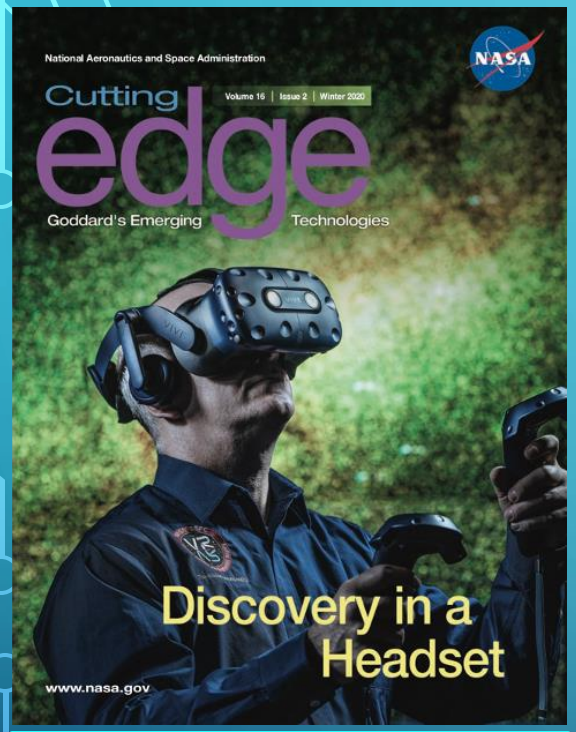
"MiniMap" view with path

VIRTUAL LANDSCAPES FOR EARTH SCIENCE AND PLANETARY SCIENCE

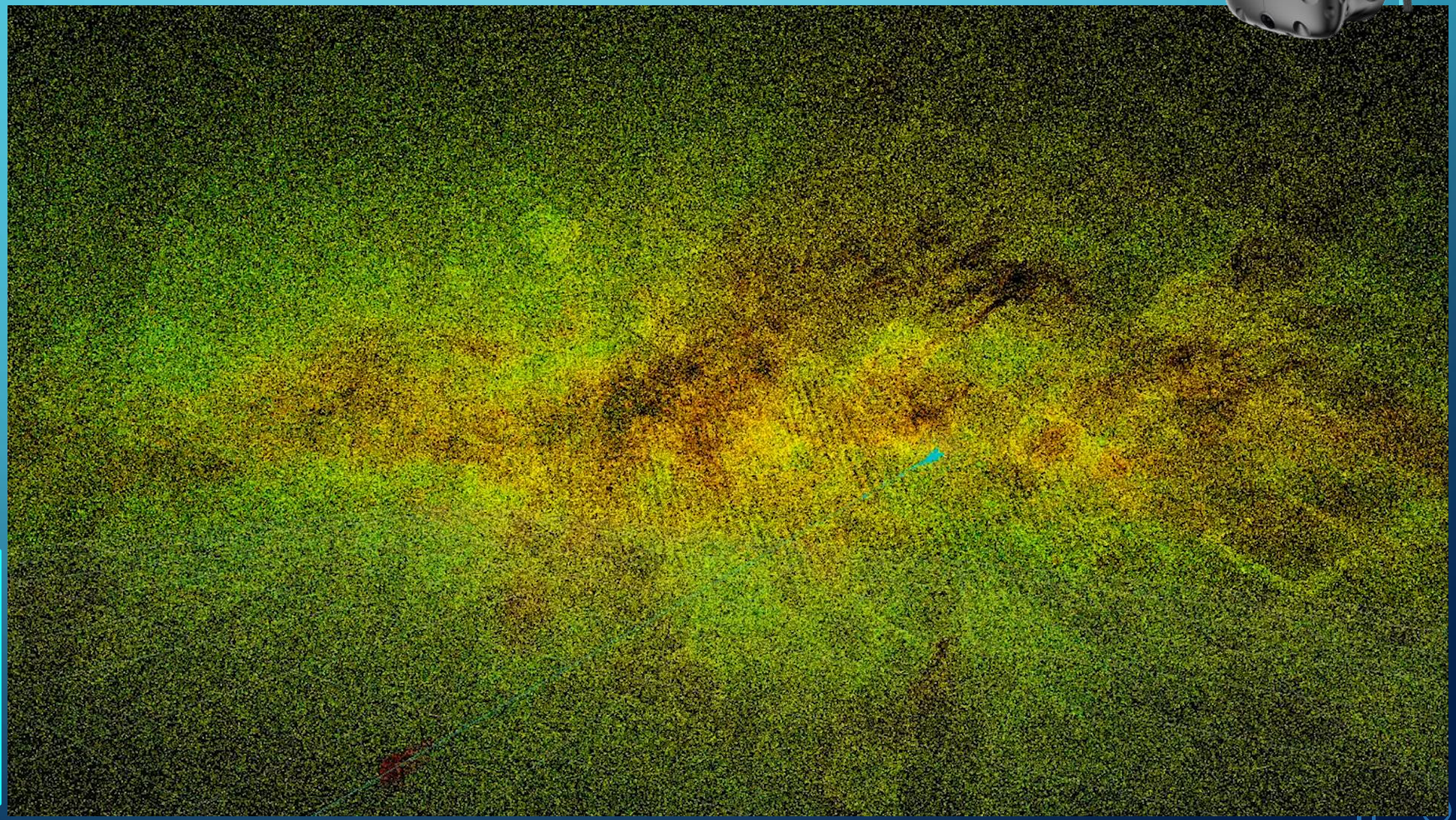
- Visualize landscape-scale point clouds as a single dataset, including colored point clouds derived from data fusion techniques
- Enable virtual collaboration
- Visit and revisit remote field sites
- Increase scientific return from NASA's investments in airborne and satellite platforms



POINT CLOUDS VR AND GAIA CITIZEN SCIENCE



- Astrophycist Marc Kuchner & Researcher Susan Higashio performed visual data analysis of moving start groups, which "would have been much harder to spot without this app"
- Porting PointCloudsVR data and algorithms to MRET for GAIA Citizen Science Project
- Imports GAIA data as Point Cloud



CONCLUSION

- XR provides several advantages
  - Quicker and more intuitive understanding of complex, spatially related, problems and situations
  - Reduced time and **money** with remote collaboration
  - Improved retention and recall.
- XR can be a valuable tool throughout the mission lifecycle (for engineering AND science tasks)
  - Combining 3D models, terrains, and point clouds for multiple space mission tasks
  - Live and Recorded telemetry from GMSEC/ROS helps with understanding and analysis
- NASA XR Open Source enables innovative approaches to the complete space mission lifecycle
  - Reduce cost/risk and barrier to access XR
  - Open Source and Partnerships benefit everyone in the space mission domain